US009471164B2

(12) United States Patent
Liu et al.

(10) **Patent No.:** **US 9,471,164 B2**
(45) **Date of Patent:** **Oct. 18, 2016**

(54) **DISPLAY DEVICE**

(71) Applicant: **Beijing FUNATE Innovation Technology Co., LTD.**, Beijing (CN)

(72) Inventors: **Liang Liu**, Beijing (CN); **Chen Feng**, Beijing (CN); **Li Qian**, Beijing (CN)

(73) Assignee: **Beijing FUNATE Innovation Technology Co., LTD.**, Beijing (CN)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 408 days.

(21) Appl. No.: **14/092,951**

(22) Filed: **Nov. 28, 2013**

(65) **Prior Publication Data**

US 2014/0125886 A1 May 8, 2014

Related U.S. Application Data

(63) Continuation of application No. 12/894,498, filed on Sep. 30, 2010, now Pat. No. 8,625,035.

(30) **Foreign Application Priority Data**

May 19, 2010 (CN) 2010 1 0176752

(51) **Int. Cl.**

G02F 1/13	(2006.01)
G06F 3/041	(2006.01)
G06F 3/044	(2006.01)
G02F 1/1343	(2006.01)

(52) **U.S. Cl.**

CPC ***G06F 3/0412*** (2013.01); ***G06F 3/044*** (2013.01); *G02F 1/134336* (2013.01)

(58) **Field of Classification Search**

CPC ... G06F 3/0412; G06F 3/044; G02F 1/13338

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0153513	A1*	6/2009	Liu	G06F 3/044 345/173
2009/0160799	A1*	6/2009	Jiang	G06F 3/045 345/173
2010/0066692	A1*	3/2010	Noguchi	G06F 3/0412 345/173
2010/0182273	A1*	7/2010	Noguchi	G02F 1/13338 345/174
2010/0295824	A1*	11/2010	Noguchi	G02F 1/13338 345/175
2014/0300580	A1*	10/2014	Noguchi	G06F 3/0412 345/174

* cited by examiner

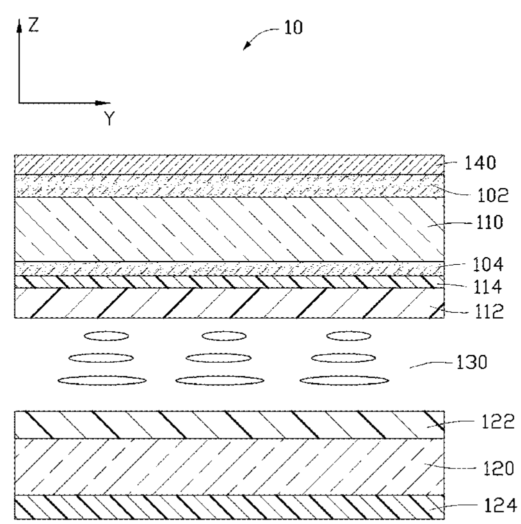
Primary Examiner — James Dudek

(74) *Attorney, Agent, or Firm* — Zhigang Ma

(57) **ABSTRACT**

A display device includes a touch panel located on a liquid crystal display screen. The touch panel includes a substrate having a first surface and a second surface opposite to the first surface, a first transparent conductive layer located on the first surface of the substrate and comprising a plurality of first conductive bands having a highest electrical conductivity in a first direction, and a second transparent conductive layer located on the second surface of the substrate and comprising a plurality of second conductive bands having a highest electrical conductivity in a second direction. The substrate and the first transparent conductive layer are common substrate and transparent conductive layer of the liquid crystal display screen.

9 Claims, 4 Drawing Sheets



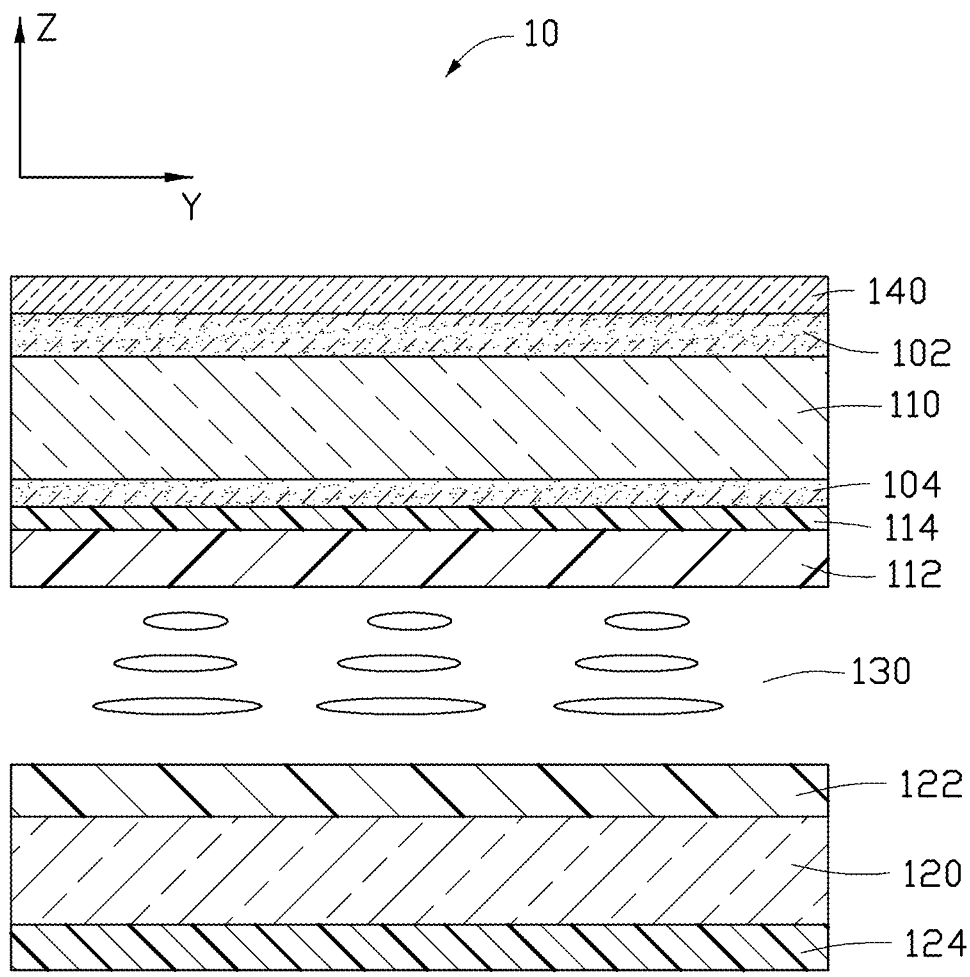


FIG. 1

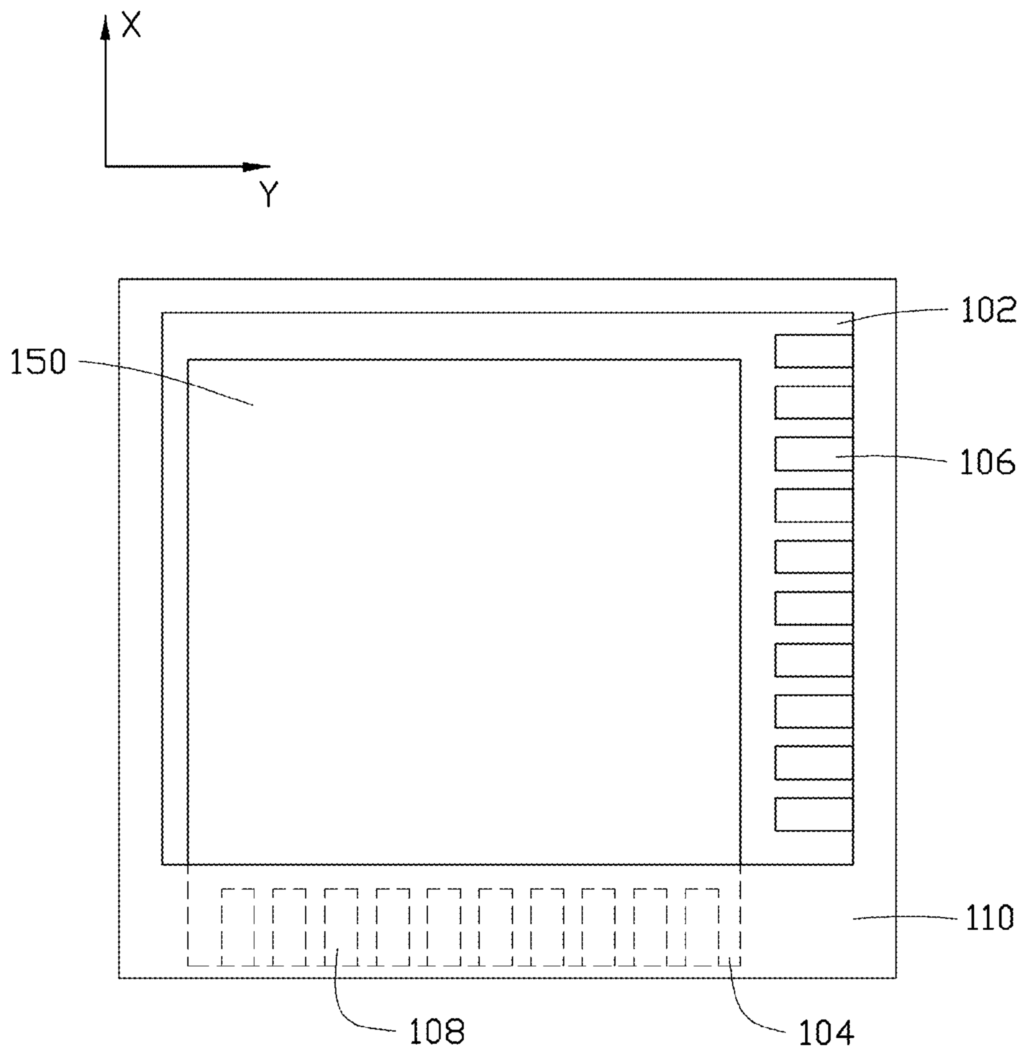


FIG. 2

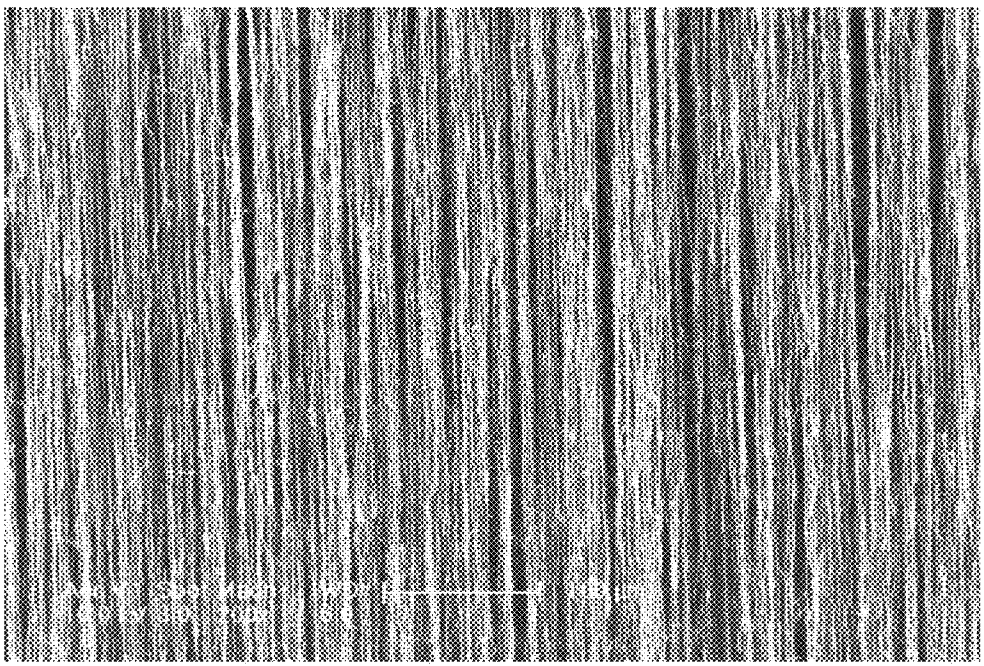


FIG. 3

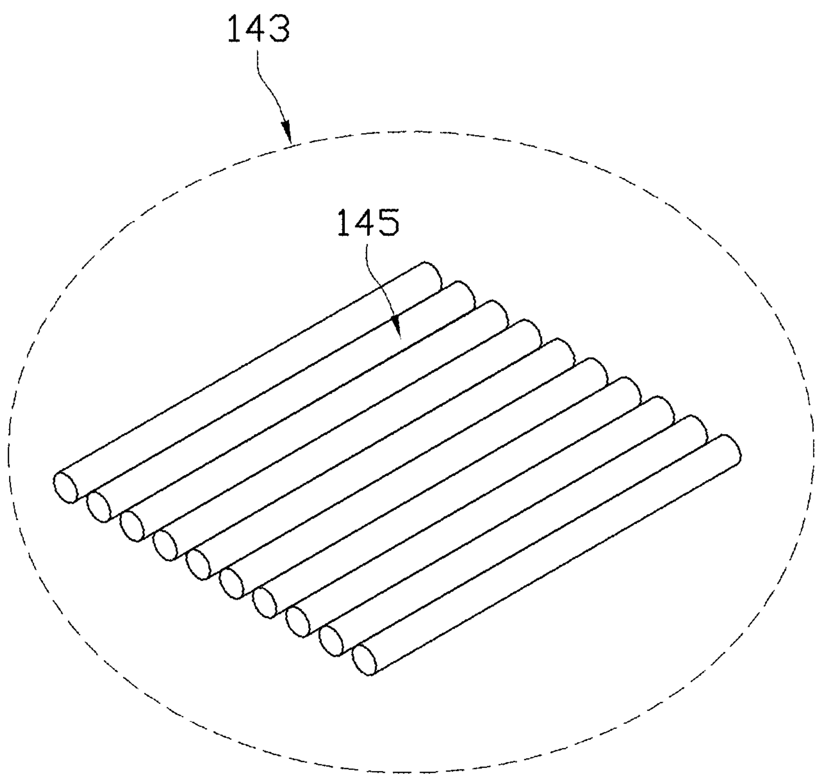


FIG. 4

DISPLAY DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of U.S. patent application Ser. No. 12/894,498, filed on Sep. 30, 2010, entitled "DISPLAY DEVICE," which claims all benefits accruing under 35 U.S.C. §119 from China Patent Application No. 201010176752.5, filed on May 19, 2010, in the China Intellectual Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND

1. Technical Field

The present disclosure relates to display devices and, particularly, to a display device, which combines a carbon nanotube based touch panel with a liquid crystal display screen.

2. Description of Related Art

Liquid crystal displays (LCDs) are typically used as the display in various devices such as computers and vehicle and airplane instrumentation. Following the advancement in recent years of various electronic apparatuses toward high performance and diversification, there has been continuous growth in the number of electronic apparatuses equipped with optically transparent touch panels at the front of their respective display devices (e.g., liquid crystal panels). Users may operate a touch panel by pressing or touching the touch panel with a finger, a pen, a stylus, or tool while visually observing the liquid crystal display through the touch panel. Therefore, a demand exists for touch panels that are superior in visibility and reliable in operation.

Resistive, capacitive, infrared, and surface acoustic wave touch panels have been developed. Capacitive touch panels are widely applied because of the high accuracy and low cost of production.

A conventional display device usually has a conventional touch panel attached to a conventional liquid crystal display through double-coated tapes. However, the volume and weight of the conventional touch panel adversely increases the entire volume and weight of the conventional display device.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the embodiments can be better understood with reference to the following drawings. The components in the drawings are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of the embodiments. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a schematic cross-section of an embodiment of a display device.

FIG. **2** is a schematic top view of the display device of FIG. **1**.

FIG. **3** shows a Scanning Electron Microscope (SEM) image of a carbon nanotube drawn film.

FIG. **4** is a schematic, enlarged view of a carbon nanotube segment.

DETAILED DESCRIPTION

The disclosure is illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to "an" or "one" embodiment in this disclosure are not necessarily to the same embodiment, and such references mean at least one.

Referring to FIG. **1** and FIG. **2**, one embodiment of a display device **10** includes a touch panel and a liquid crystal display screen, which shares components with the touch panel.

In one embodiment, the touch panel can be a multi-touch capacitive touch panel. The multi-touch capacitive touch panel can include a common substrate **110**, a first transparent conductive layer **102**, a second transparent conductive layer **104**, a number of first electrodes **106**, and a number of second electrodes **108**. Both the first transparent conductive layer **102** and the second transparent conductive layer **104** have good anisotropic electrical conductivity. The first transparent conductive layer **102** and the second transparent conductive layer **104** both have good light transmittance.

As shown in FIG. **1** and FIG. **2**, the first transparent conductive layer **102** is disposed on a top surface of the common substrate **110**. The first electrodes **106** are electrically connected with the first transparent conductive layer **102**. The first electrodes **106** are disposed on one side of the first transparent conductive layer **102** at unequal intervals. The first electrodes **106** are formed in a row extending along a first direction X.

The second transparent conductive layer **104** is disposed on a bottom surface of the common substrate **110**. The second electrodes **108** are electrically connected with the second transparent conductive layer **104**. The second electrodes **108** can be disposed on one side of the second transparent conductive layer **104** at unequal intervals. The second electrodes **108** can be formed in a row extending along a second direction Y. The first direction X can be substantially perpendicular to the second direction Y. In other embodiments, the first direction X can cross with the second direction Y at an acute angle or an obtuse angle defined therebetween.

The first transparent conductive layer **102** overlaps the second transparent conductive layer **104** in a third direction Z, defined from the second transparent conductive layer **104** to the first transparent conductive layer **102**. The third direction Z can be substantially perpendicular to the first direction X and the second direction Y. A touch region **150** is formed at the overlapped portions between the first transparent conductive layer **102** and the second transparent conductive layer **104**.

The liquid crystal display screen shares the common substrate **110** and the second transparent conductive layer **104** with the above described touch panel. The liquid crystal display screen can further include a first polarizer **114**, a first alignment layer **112**, a liquid crystal layer **130**, a second alignment layer **122**, a thin film transistor panel **120**, and a second polarizer **124**.

The first polarizer **114** is disposed on a lower surface of the second transparent conductive layer **104**. The first alignment layer **112** is disposed on a lower surface of the first polarizer **114**. The second alignment layer **122** is disposed on an upper surface of the thin film transistor panel **120** and opposite to the first alignment layer **112**. The liquid crystal layer **130** is disposed between the first alignment layer **112** and the second alignment layer **122**. The second polarizer **124** is disposed on a lower surface of the thin film transistor panel **120**.

The common substrate **110** can be used as a base of the multi-touch capacitive touch panel and as an upper substrate of the liquid crystal display screen. The second transparent conductive layer **104** can be used as a transparent conductive layer of the multi-touch capacitive touch panel to sense touch positions, and as an upper electrode of the liquid crystal display screen to apply a voltage to the liquid crystal layer **130**. Thus, the display device **10** can have a low thickness, simple structure, and low cost.

In some embodiments, the first transparent conductive layer **102** can be a first carbon nanotube layer, and the second transparent conductive layer **104** can be a second carbon nanotube layer. Both the first carbon nanotube layer and the second carbon nanotube layer can be a carbon nanotube film having anisotropic electrical conductivity. Carbon nanotubes of the first carbon nanotube layer can be substantially arranged along the second direction Y, so that the first carbon nanotube layer has a larger electrical conductivity at the second direction Y than at other directions. Carbon nanotubes of the second carbon nanotube layer can be substantially arranged along the first direction X, so that the second carbon nanotube layer has a larger electrical conductivity at the first direction X than at other directions.

In some embodiments, both the first carbon nanotube layer and the second carbon nanotube layer comprise carbon nanotubes. In some embodiments, each of the first carbon nanotube layer and the second carbon nanotube layer can be or include at least one carbon nanotube drawn film.

The carbon nanotube drawn film includes a plurality of carbon nanotubes that can be arranged substantially parallel to a surface of the carbon nanotube drawn film. A large number of the carbon nanotubes in the carbon nanotube drawn film can be oriented along a preferred orientation, meaning that a large number of the carbon nanotubes in the carbon nanotube drawn film are arranged substantially along the same direction. An end of one carbon nanotube is joined to another end of an adjacent carbon nanotube arranged substantially along the same direction, by Van der Waals attractive force. A small number of the carbon nanotubes may be randomly arranged in the carbon nanotube drawn film, and has a small if not negligible effect on the larger number of the carbon nanotubes in the carbon nanotube drawn film arranged substantially along the same direction. The carbon nanotube drawn film is capable of forming a free-standing structure. The term "free-standing structure" can be defined as a structure that does not have to be supported by a substrate. For example, a free standing structure can sustain the weight of itself when it is hoisted by a portion thereof without any significant damage to its structural integrity. So, if the carbon nanotube drawn film is placed between two separate supporters, a portion of the carbon nanotube drawn film, not in contact with the two supporters, would be suspended between the two supporters and yet maintain film structural integrity. The free-standing structure of the carbon nanotube drawn film is realized by the successive carbon nanotubes joined end to end by Van der Waals attractive force.

It can be appreciated that some variation can occur in the orientation of the carbon nanotubes in the carbon nanotube drawn film as can be seen in FIG. **3**. Microscopically, the carbon nanotubes oriented substantially along the same direction may not be perfectly aligned in a straight line, and some curve portions may exist. It can be understood that some carbon nanotubes located substantially side by side and oriented along the same direction being contact with each other can not be excluded.

More specifically, referring to FIG. **4**, the carbon nanotube drawn film includes a plurality of successively oriented carbon nanotube segments **143** joined end-to-end by Van der Waals attractive force therebetween. Each carbon nanotube segment **143** includes a plurality of carbon nanotubes **145** substantially parallel to each other, and joined by Van der Waals attractive force therebetween. The carbon nanotube segments **143** can vary in width, thickness, uniformity, and shape. The carbon nanotubes **145** in the carbon nanotube drawn film are also substantially oriented along a preferred orientation.

In one embodiment, the carbon nanotube drawn film can be drawn out from an array of carbon nanotubes. The carbon nanotube drawn film can be formed by selecting one or more carbon nanotubes having a predetermined width from the array of carbon nanotubes, and pulling the carbon nanotubes at a roughly uniform speed to form carbon nanotube segments that are joined end to end to achieve a uniform carbon nanotube drawn film.

The carbon nanotube segments can be selected by using a tool, such as adhesive tape, pliers, tweezers, or other tools allowing multiple carbon nanotubes to be gripped and pulled simultaneously to contact with the array of carbon nanotubes. Referring to FIG. **4**, each carbon nanotube segment **143** includes a plurality of carbon nanotubes **145** substantially parallel to each other, and combined by Van der Waals attractive force therebetween. The pulling direction can be substantially perpendicular to the growing direction of the array of carbon nanotubes.

The drawn carbon nanotube film has the smallest resistance at the pulling direction, and the largest resistance at a direction substantially perpendicular to the pulling direction.

In one embodiment, both of the first carbon nanotube layer and the second carbon nanotube layer includes a number of carbon nanotube drawn films located side by side or stacked with each other. Carbon nanotubes of the first carbon nanotube layer are arranged substantially along the second direction Y. Carbon nanotubes of the second carbon nanotube layer are arranged substantially along the first direction X. The length and width of the carbon nanotube drawn films are not limited, because the carbon nanotube drawn films can be located side by side or stacked with each other in the first carbon nanotube layer and the second carbon nanotube layer. In one embodiment, each carbon nanotube drawn film has a light transmittance greater than 85%, and the number of layers of the carbon nanotube drawn films is not limited, so long as the first carbon nanotube layer and the second carbon nanotube layer have proper light transmittance.

In some embodiments, each of the first carbon nanotube layer and the second carbon nanotube layer includes a carbon nanotube composite film. The carbon nanotube composite film includes a carbon nanotube drawn film and polymer materials infiltrating the carbon nanotube drawn film. Spaces can exist between adjacent carbon nanotubes in the carbon nanotube drawn film, and thus the carbon nanotube drawn film includes a number of micropores defined by the adjacent carbon nanotubes therein. The polymer material is filled into the micropores of the carbon nanotube drawn film to form the carbon nanotube composite film. The polymer materials can be distributed uniformly in the carbon nanotube composite film. The carbon nanotube composite film can include one or more carbon nanotube drawn films. The carbon nanotube composite film can have a uniform thickness. A thickness of the carbon nanotube composite film is only limited by the degree of transparency desired. In one embodiment, the thickness of the carbon nanotube composite film can range from about 0.5 nanometers to about 100 microns. The polymer material can be transparent, and not limited to a specific material. The polymer material can be polystyrene, polyethylene, polycarbonate, polymethyl methacrylate (PMMA), polycarbonate (PC), polyethylene terephthalate (PET), Benzo Cyclo Butene (BCB), or polyalkenamer. In one embodiment, the polymer material is PMMA.

In some embodiments, each of the first carbon nanotube layer and the second carbon nanotube layer includes at least one etched or laser-treated carbon nanotube drawn film. The etched or laser-treated carbon nanotube drawn film has an enhanced anisotropic electrical conductivity. For example, a number of cutting lines can be formed in the first carbon nanotube layer along the second direction through laser or etching.

The common substrate **110** can be a transparent plate. The common substrate **110** can be made of glass, quartz, diamond, plastic or resin. The thickness of the common substrate **110** can range from about 1 millimeter to about 1 centimeter. In one embodiment, the common substrate **110** is a PET film and the thickness of the common substrate **110** is about 2 millimeters.

The first electrodes **106** and the second electrodes **108** can include conductive materials, such as metals, conductive polymer materials, or carbon nanotubes. The metals can be gold, silver, copper or any other metal having a good conductivity. The conductive polymer materials can be polyacetylene, polyparaphenylene, polyaniline, or polythiophene. In one embodiment, the first electrodes **106** and the second electrodes **108** can be made of conductive silver pastes.

A transparent protective film **140** can be further located on the upper surface of the first transparent conductive layer **102**. The material of the transparent protective film **140** can be silicon nitride, silicon dioxide, BCB, polyester, acrylic resin, PET, or any combination thereof. The transparent protective film **140** can also be a plastic film treated with surface hardening treatment. The transparent protective film **140** can reduce glare or reflection. In one embodiment, the material of the transparent protective film **140** is PET.

Because both of the first transparent conductive layer **102** and the second transparent conductive layer **104** have good anisotropic electrical conductivity, each portion of the first transparent conductive layer **102** contacting one of the first electrodes **106** can be equal to a conductive band. Similarly, the second transparent conductive layer **104** can also be equal to a number of conductive bands. The conductive bands of the first transparent conductive layer **102** are substantially perpendicular to the conductive bands of the second transparent conductive layer **104**. Thus, a number of capacitances are formed at the intersections of the conductive bands of the first transparent conductive layer **102** and the second transparent conductive layer **104**. In operation of the touch panel, one or more contacts can be made with the touch panel from one or more contact tools (not shown), such as fingers or a stylus. Capacitances of the contact points will change and can be detected by external circuits connected with the first electrodes **106** and the second electrodes **108**. The coordinates of the contact points on the touch panel can be obtained.

In the liquid crystal display screen, a material of the first polarizer **114** can be conventional polarizing material, such as dichroism organic polymer materials. In some embodiments, the material of the first polarizer **114** can be iodine material or dyestuff material.

The second polarizer **124** can be made of the same material as the first polarizer **114**. The second polarizer **124** is used to polarize the light beams emitted from the light guide plate (not shown) located on the surface of the liquid crystal display screen facing away from the thin film transistor panel **120**, and thus acquire polarized light beams along a same direction. The polarization direction of the second polarizer **124** is substantially perpendicular to the polarization direction of the first polarizer **114**.

The first alignment layer **112** can include a number of substantially parallel first grooves (not shown) formed thereon. The first grooves are located on a lower surface of the first alignment layer **112** opposing the liquid crystal layer **130**. The first grooves are used to make the liquid crystal molecules align along a same direction. The second alignment layer **122** can include a number of substantially parallel second grooves (not shown) formed thereon. The second grooves are located on an upper surface of the second alignment layer **122** opposing the liquid crystal layer **130**.

An alignment direction of the first grooves is substantially perpendicular to an alignment direction of the second grooves. The second grooves are used to make the liquid crystal molecules align substantially along a same direction. Because the alignment direction of the first grooves is substantially perpendicular to the alignment direction of the second grooves, the alignment direction of the liquid crystal molecules differ by about 90 degrees between the first alignment layer **112** and the second alignment layer **122**, which play a role of shifting the light beams polarized by the second polarizer **122** by 90 degrees.

The material of the first alignment layer **112** and the second alignment layer **122** can be polystyrenes and derivatives of the polystyrenes, polyimides, polyvinyl alcohols, polyesters, epoxy resins, polyurethanes, or other polysilanes. The first grooves and the second grooves can be formed by a rubbing method, a tilt deposition method, a micro-grooves treatment method, or a SiOx-depositing method. In one embodiment, a material of the first alignment layer **112** and the second alignment layer **122** is polyimide and a thickness thereof ranges from about 1 micrometer to about 50 micrometers.

The liquid crystal layer **130** includes a number of cigar shaped liquid crystal molecules. Understandably, the liquid crystal layer **130** can also be made of other conventional suitable materials, such as alkyl benzoic acid, alkyl cyclohexyl acid, alkyl cyclohexyl-phenol, and phenyl cyclohexane. A thickness of the liquid crystal layer **130** ranges from about 1 micrometer to about 50 micrometers. In one embodiment, a thickness of the liquid crystal layer **130** is about 5 micrometers.

The detailed structure of the thin film transistor panel **120** is not shown in FIG. **1**. It is to be understood that the thin film transistor panel **120** can further include a transparent base, a number of thin film transistors located on the transparent base, a number of pixel electrodes, and a display driver circuit (not shown). The thin film transistors correspond to the pixel electrodes in a one-to-one manner. The thin film transistors are connected to the display driver circuit by the source lines and gate lines. The pixel electrodes are controlled to cooperate with the second transparent conductive layer **104**, to apply a voltage to the liquid crystal layer **130**. The pixel electrodes correspond to the touch region **150**.

As described above, the liquid crystal display screen shares the common substrate **110** and the second transparent conductive layer **104** with the above described touch panel. Thus, the display device **10** can have a low thickness, simple structure, and low cost.

It is to be understood that the described embodiments are intended to illustrate rather than limit the disclosure. Any elements described in accordance with any embodiments is understood that they can be used in addition or substituted in other embodiments. Embodiments can also be used together. Variations may be made to the embodiments without departing from the spirit of the disclosure. The disclosure illustrates but does not restrict the scope of the disclosure.

What is claimed is:

1. A display device comprising:

a liquid crystal display screen comprising:

a substrate having a first surface and a second surface opposite to the first surface; and

a first electrode located on the first surface of the substrate and comprising a plurality of first conductive bands having a highest electrical conductivity in a first direction;

a transparent conductive layer located on the second surface of the substrate, wherein the transparent conductive layer comprises a plurality of second conductive bands having a highest electrical conductivity in a second direction; and

a plurality of capacitances formed at intersections of the plurality of first conductive bands and the plurality of second conductive bands;

wherein the liquid crystal display screen further comprises:

a first alignment layer located on the first electrode;

a thin film transistor panel spaced from the substrate and having a third surface facing the first surface of the substrate;

a second electrode located on the third surface of the thin film transistor panel;

a second alignment layer located on the second electrode;

a liquid crystal layer located between the first alignment layer and the second alignment layer;

a first polarizer located between the first electrode and the first alignment layer; and

a second polarizer located on a fourth surface of the thin film transistor panel opposite to the third surface.

2. The display device of claim **1**, wherein the first electrode comprises a first carbon nanotube drawn film having a plurality of first carbon nanotubes substantially arranged along the first direction, and the transparent conductive layer comprises a second carbon nanotube drawn film having a plurality of second carbon nanotubes substantially arranged along the second direction.

3. The display device of claim **2**, wherein the plurality of first carbon nanotubes are joined end-to-end by Van der Waals attractive force therebetween, and the plurality of second carbon nanotubes are joined end-to-end by Van der Waals attractive force therebetween.

4. The display device of claim **1**, wherein at least one of the first electrode and the transparent conductive layer comprises a carbon nanotube drawn film having a plurality of carbon nanotubes substantially arranged along a same direction and joined end-to-end by Van der Waals attractive force therebetween.

5. The display device of claim **4**, wherein at least one of the first electrode and the transparent conductive layer comprises a plurality of carbon nanotube drawn films located side by side.

6. The display device of claim **4**, wherein at least one of the first electrode and the transparent conductive layer comprises a plurality of carbon nanotube drawn films stacked with each other.

7. The display device of claim **1**, wherein at least one of the first electrode and the transparent conductive layer comprises a carbon nanotube drawn film and polymer materials infiltrating the carbon nanotube drawn film.

8. The display device of claim **1**, wherein the first direction is substantially perpendicular to the second direction.

9. The display device of claim **1**, further comprising a transparent protective film located on the transparent conductive layer.

* * * * *